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the constituent elements of organisms. The study of physiological and pathological variations that elucidate correlations will, therefore, be a most powerful factor in the discussion of the problem of variability.

This point of view coincides closely with that of Rudolf Virchow who has always emphasized that the clue for the problems of variability must be looked for in the study of cellular variation.

Under certain simplified assumptions the problem, as here defined, may be made amenable to statistical treatment. If all the contributory causes of variation are given equal weight, and if it is assumed that the index of correlation for all the groups is the same, then it is only necessary to determine four unknown quantities: the total number of causes (or correlated groups); the probable number of causes (or correlated groups); the amount of influence of each cause (or correlated group) upon the whole organism; the variability of the effect of each cause (or correlated group) upon the whole organism. These few data can be calculated without any great difficulty from the averages of the first four powers of the individual variations. This method may be serviceable as long as the actual correlations are unknown.

Still another conclusion may be drawn from our considerations. We have seen that the variability of an organism depends upon the correlations of its elements, and that the variability must be the greater the closer these correlations and the less the number of correlated groups. At the same time, the variations will be the more likely to have skew distributions, the less the number of correlated groups. A disturbance in one element of an organism thus constituted must, therefore, result in a considerable variation of the whole. That is to say, that in the case of skew distributions of variations we may expect sudden transformations of type due to small causes. In

organisms in which the variability is symmetrical, we may generally expect the whole form to be controlled by many independent causes, or by many independent groups of correlated elements. In this case, the changes of form due to small changes of conditions will probably be less marked.

The principal advantage of the method of considering variation that has been here suggested is that the occurrence of variations in fixed lines, that are so difficult to understand, may be considered as a result of chance variation of small elements and of physiological correlation. Both of these are much more readily understood than a variation of form that does not show any immediate relation to the causes producing the variation.

It has often been asserted, or assumed, that skew distribution of variations is a proof of the effect of selection, or of some other kind of instability of type. Our considerations have shown that this is not necessarily the case. Skew distributions may be found in stable forms. On the whole, it does not seem possible to discover by purely statistical methods the causes of skewness. The numerical material obtained by measurements can be made to fit satisfactorily many theories that would account for the skewness. It is necessary to base such theories on biological investigations and to subordinate our statistical methods to the biological point of view. Otherwise the result of statistical inquiry will be of little use and may even become quite misleading.

FRANZ BOAS.

ON THE TRUE NATURE OF *TAMIOSOMA*.*

IN 1856 the late T. A. Conrad described a remarkable fossil from California, under the name of *Tamiosoma gregaria*, composed of large tubes with a longitudinal cellular

* Communicated by permission of the Director of the U. S. Geological Survey.

structure, closed and tapering to a relatively small point of attachment below, nearly filled with a vesicular mass of shell laminae internally, preserving a smooth-walled body cavity with a reflexed margin at the upper end, without any trace of subdivision in the walls, or dentiform processes. He pointed out some similarities in the form of the aperture to the sessile barnacles (*Balanus*) from which animals the undivided tube structure seemed to definitely separate the new organism. Subsequently he described an imperfect specimen as a *Balanus* (*B. estrellanus* Conrad, 1857), but still later (1864) he referred it to *Radiolites*, in the course of some rectifications of his earlier papers, and stated that it was characteristic of the Cretaceous of California.

In 1866 Gabb stated ('Pal. Cal.,' II., p. 62) that it was a fossil of 'the Bituminous shale, the best marked member of our Upper Miocene,' and referred it to the Hippuritidae, an opinion provisionally accepted by Stoliczka in 1871,* notwithstanding the fact that the upper valve was unknown and the supposed lower valve showed no traces of muscular impressions, pallial line or tooth sockets. Tyron,† in 1884, copies Gabb's remarks without comment. Zittel‡ and Barrois, in 1887, regarded it as a problematical organism possibly referable to the corals, while in the same year Fischer expresses the opinion§ that it is more like a large barnacle than a Hippurite. Most of the manuals and check-lists prudently omit all reference to it.

During the past season Mr. Homer Hamlin of Los Angeles sent to the writer a collection of fossils from southern California containing numerous Miocene types,

*'Cretaceous Pelecypoda of India,' p. 239.

†'Structural and Systematic Conch.,' III., p. 206.

‡'Traité de Pal.,' II., p. 86.

§'Man. de Conchyl.,' p. 1064.

including *Lyropecten magnolia* and *L. Heermannii* Conrad, from a horizon of which the matrix is a cemented calcareous gravel (not the bituminous shale), containing several examples of *Tamiosoma*; not only the gregarious colonies, such as were described by Conrad, but also solitary individuals and certain flat saucer-like, concentric valves with reflected edges, which were naturally taken to be the long-sought upper valves. One solitary individual appeared to have this flat valve *in situ* and a sagittal section of it was made, to study the relations of the body cavity. It may be mentioned in passing that all the material in the beds from which these fossils came has been more or less crushed so that perfect specimens are extremely rare.

The result of the sectionizing was most unexpected. There was no body cavity and the flat saucer-like portion proved to be merely the basal portion of the tube, which in solitary individuals starts from an extremely small point of attachment to some object and grows concentrically in a flat form until it is an inch or two in diameter, after which it changes its manner of growth and rises in columnar fashion. In the gregarious groups the growth forms an inverted cone, owing to the mechanical difficulties in the way of lateral expansion. A section of the shelly matter showed that it is entirely destitute of the prismatic layer of the Hippuritidae, and that the structure of the shell is precisely that of the sessile cirripedes. Since the tube is entire and not divided into valves, and is quite destitute of any radial structure, it was evident that the organism is not homologous with the valvular case of the sessile barnacles, which is always divided into plates more or less distinctly fused with one another, and that it cannot be a coral.

The only remaining alternative then appears to be that the fossil described by Conrad is homologous, not with the valvu-

lar portion of *Balanus*, but with the base, which in the latter genus is not only entire, but under suitable conditions assumes a tubular conical form, and in one species, the *Balanus laevis* of Darwin, sometimes has the lower portion of this tube more or less filled with a vesicular mass of shell substance closely resembling the tube of *Tamiosoma*.* This conclusion was fortified by the discovery of an undoubted species of *Balanus* in the same horizon as that of *Tamiosoma*, forming a tubular base like that of *B. laevis*, though much smaller, in the proximal portion of which a certain amount of vesicular filling had taken place. Lastly, complete confirmation was attained through the kindness of the authorities of the State Mining Bureau of California which at the intercession of Dr. J. C. Merriam, of the University of California, forwarded a unique specimen which had been supposed to exhibit an 'upper valve,' but in which the subconic base filled this rôle, while a careful cleaning of the much-crushed but otherwise nearly intact 'base' revealed the remains of six very solid valves typical of the genus *Balanus*, and the cavity, now filled with gravel and fragments of the shell, in which the soft parts of the animal had originally been enclosed. These valves were so crushed and worn that a complete figure of the valvular summit of *Tamiosoma* is not yet attainable, but the fact that the valves are smooth, except for the rude concentric rugosities due to resting stages and other exigencies of growth, and that they agree with the typical *Balanus* in number and general character, is conclusively demonstrated.†

It is interesting to discover new types of

* Darwin, Mon. Cirripedia, *Balanidae*, p. 227, 1854. See figure of the variety *coquimbensis*, Plate 4, Fig. 2a, giving a section of the tubular base, partly filled with vesicular septa.

† Since the above was written a letter from Mr. Hamlin announces the discovery of a number of complete specimens with the valves.

animal organisms, but perhaps still more so to be able to place those already known to some extent, but whose relations, in the absence of complete information, have been so differently estimated as in the present case. It only remains for systematic students of the cirripedes to determine whether the notable peculiarities of growth of this singular fossil warrant the retention of the name *Tamiosoma* in a subgeneric or sectional sense, or whether it shall be relegated to the genus *Balanus* as a synonym.

Some time since, the supposed occurrence of *Radiolites* in a bed of clay pierced for a tunnel in the city of Los Angeles was noted in SCIENCE. A further examination of fossils collected from these clays by Mr. Hamlin shows that sixty per cent. of the mollusks are recent species, and the age of the deposit therefore Pliocene. Mr. T. W. Vaughan is confident that the fossil which was taken for the smaller valve of the supposed *Radiolites* is a solitary coral; and, while the other portion still remains problematical, it is highly improbable that it belongs to the group of Rudistes.

WM. HEALEY DALL.

THE RELATIVE PROGRESS OF THE COAL-TAR INDUSTRY IN ENGLAND AND GERMANY DURING THE PAST FIFTEEN YEARS.*

THE coal-tar industry is the flower of the chemical industries. It represents the highest development of applied chemical research and chemical engineering, and a country which allows the most scientific branch of chemical industry to languish cannot expect to maintain preeminence

* From a paper by Arthur C. Green read before the British Association (Section of Chemistry) at the Glasgow Meeting, 1901. This accurate statement of the present status of the coal-tar industry, and incidentally of the whole chemical industry, is of interest, not only to the audience for which it was prepared, but also to Americans. For this reason the most important portions of the paper are here presented.